Import Geometrics Plotrefra .VS & Remove trigger jitter & Smooth invert marine refraction profile L-230_VS v. 5.01 :

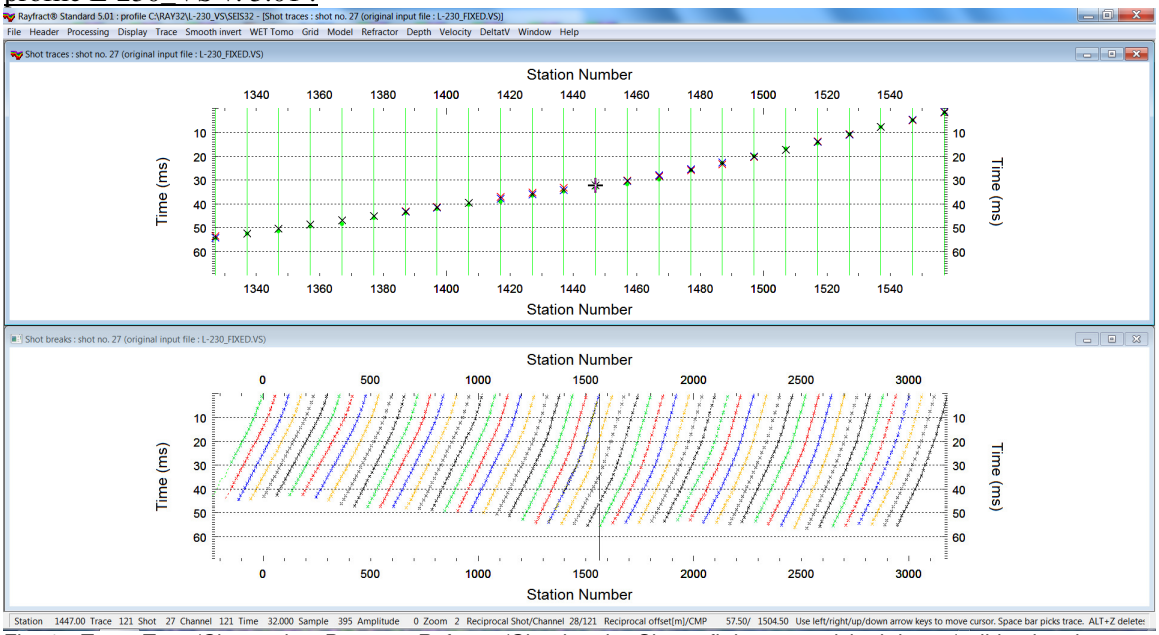

Fig. 1 : Top : *Trace|Shot gather*. Bottom : *Refractor|Shot breaks*. Shows fit between picked times (solid colored curves, red crosses) and modeled times (dashed colored curves, blue crosses). Green dots are your reciprocal picks.

To create the profile database, import the data and browse the imported shots do these steps :

- ***File|New Profile***…, set *File name* to **`L-230_VS`** and click *Save button*
- in the prompt shown next (Fig. 4) click ***No*** button to determine ***Profile start*** / first receiver station number by dividing the first receiver position in the .VS file by our *Station spacing* (Fig. 2)
- in ***Header|Profile***… select *Line type* **`Refraction spread/line`** . Set *Station spacing* to 0.5 m. See Fig. 2.
- in ***Header|Profile***… check box *Force grid cell size* and set field *Cell size [m]* to 0.5m (Fig. 2)
- in ***Header|Profile***… check box ***Extrapolate tomograms*** and set field ***Extrapolate [station spacings]*** to 30. See Fig. 2.
- unzip archive **`https://rayfract.com/tutorials/L-230_VS.zip`** containing file **`L-230_fixed.VS`** in directory **`C:\RAY32\L-230_VS\INPUT`**
- select ***File|Import Data***… and set *Import data type* to **`Geometrics Plotrefa .VS`**. See Fig. 3.
- click ***Select*** *button* and navigate into **`C:\RAY32\L-230_VS\INPUT`**
- select file **`L-230_fixed.VS`** & click *Open*
- leave *Default spread type* at **`10: 360 channels`**
- click ***Import shots button*** .
- in our ***Import shot*** dialog leave ***Layout start [station no.]*** and ***Shot pos. [station no.]*** as displayed for each shot. Just click *Read button* to import the shot. Click *Read* button repeatedly to import all 54 shots displayed.
- select *Trace|Shot gather* to obtain Fig. 1
- click on title bar of *Refractor|Shot breaks* window (Fig. 1 bottom) and press ALT+P. Edit *Maximum time* to 70 ms & press ENTER key to redisplay. Do the same for *Trace|Shot gather* window (Fig. 1 top).
- browse shots in *Trace|Shot gather* window with F7/F8 (Fig. 1 top)
- select *Processing menu* item ***Remove trigger jitter for all shots***

Run default fail-safe Smooth inversion with 1D-gradient laterally averaged starting model :

- check option *Grid|Receiver station ticks on top axis*
- check option *Grid|CS_CENTERED font for shot points and receivers*
- edit *Grid|Surfer plot Limits* as in Fig. 8
- select *Model|WDVS Smoothing* and click radio button *restore WET smoothing and discard WDVS smoothing only*. Leave box *use WDVS for forward modeling of traveltimes* unchecked (Fig. 9).
- uncheck blanking option *WET Tomo|Blank|Blank below envelope after last iteration*
- select ***Smooth invert|WET with 1D-gradient initial model***
- dismiss prompt *Shot point spacing is much too wide* (Fig. 11). This prompt is not relevant for marine refraction data recorded at continuous incremental positions with towed streamer.
- wait for the 1D-gradient starting model to display as in Fig. 5
- confirm prompt to continue with WET inversion to obtain WET output shown in Fig. 6 & 7

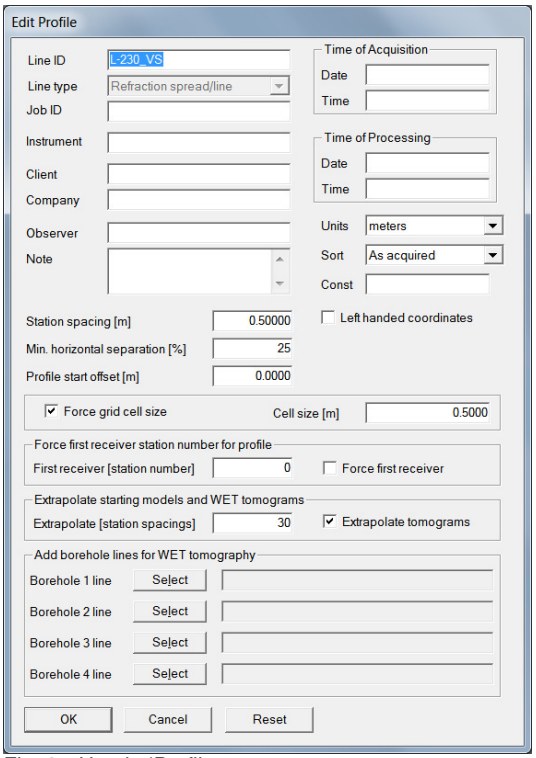

Fig. 2 : *Header|Profile*

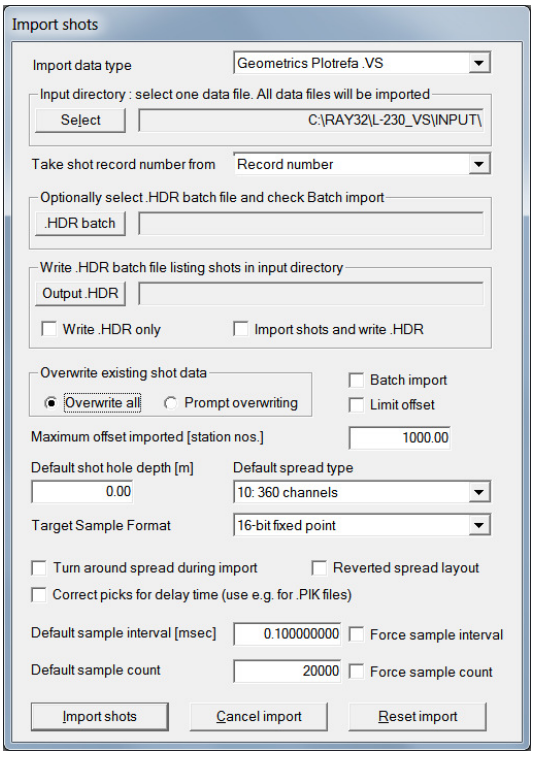

Fig. 3 : *File|Import Data*

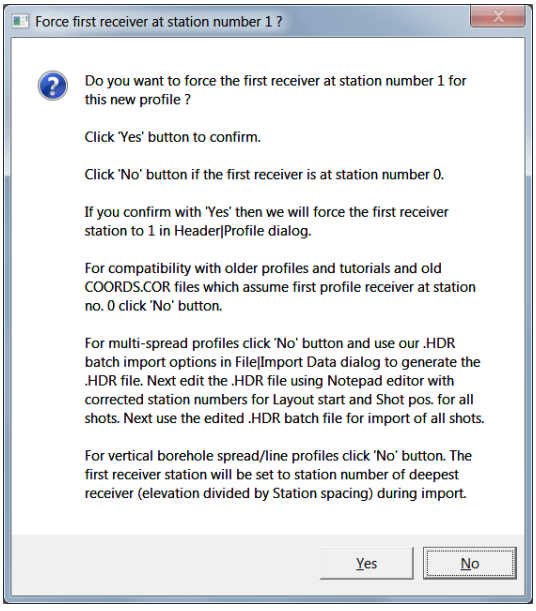

Fig. 4 : click *No* button to determine the first receiver station number for this profile from the Geometrics Plotrefa .VS by dividing the first receiver position in the .VS file by our ***Header|Profile|Station spacing*** (Fig. 2).

For compatibility with older profiles and tutorials and old COORDS.COR files which assume first profile receiver at station no. 0 click No button. For multi-spread profiles click No button and use our .HDR batch import options in *File|Import Data* dialog to generate the .HDR file. Next edit the .HDR file using MS Notepad editor with corrected station numbers for *Layout start* and *Shot pos.* for all shots. Next use the edited .HDR batch file for import of all shots.

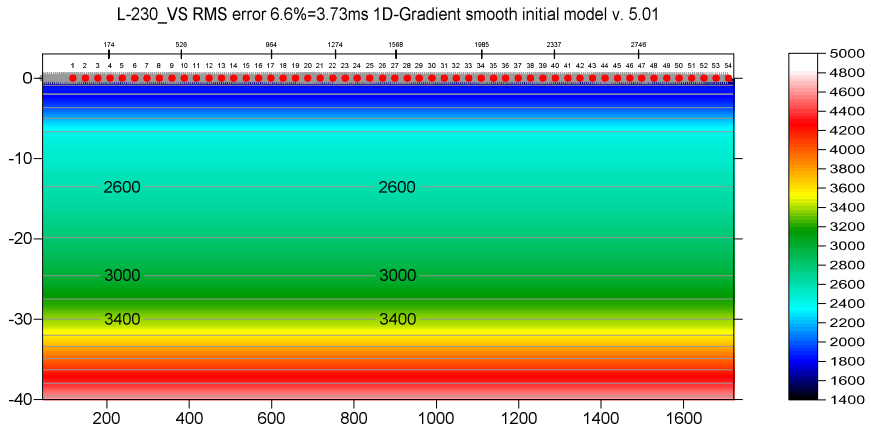

Fig. 5 : 1D-gradient starting model obtained with *Smooth invert|WET with 1D-gradient initial model.*

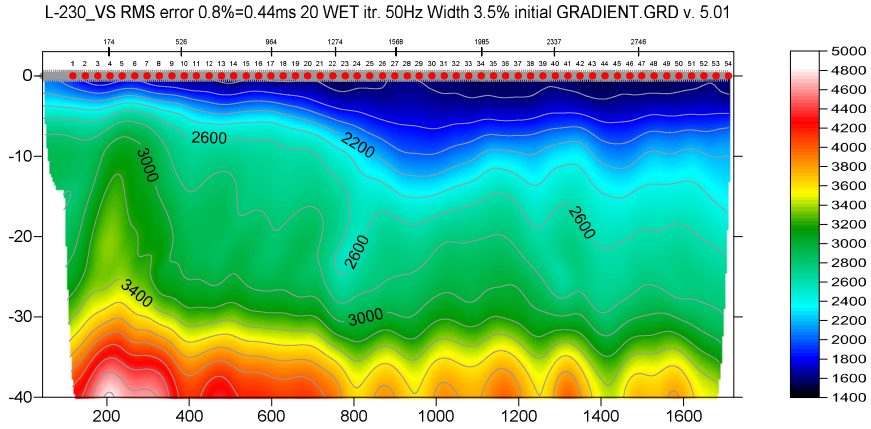

Fig. 6 : 2D WET output obtained with *Smooth invert|WET with 1D-gradient initial model* & starting model shown in Fig. 5. 20 WET iterations using Steepest Descent method & Gaussian update weighting & full WET smoothing. Don't discard WET smoothing after forward modeling. Leave WDVS disabled (Fig. 9).

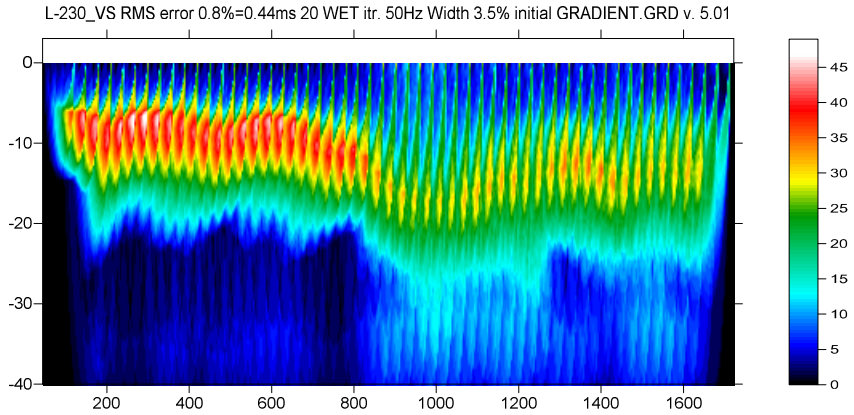

Fig. 7 : WET wavepath coverage plot obtained with Fig. 6. Unit is wavepaths per grid cell.

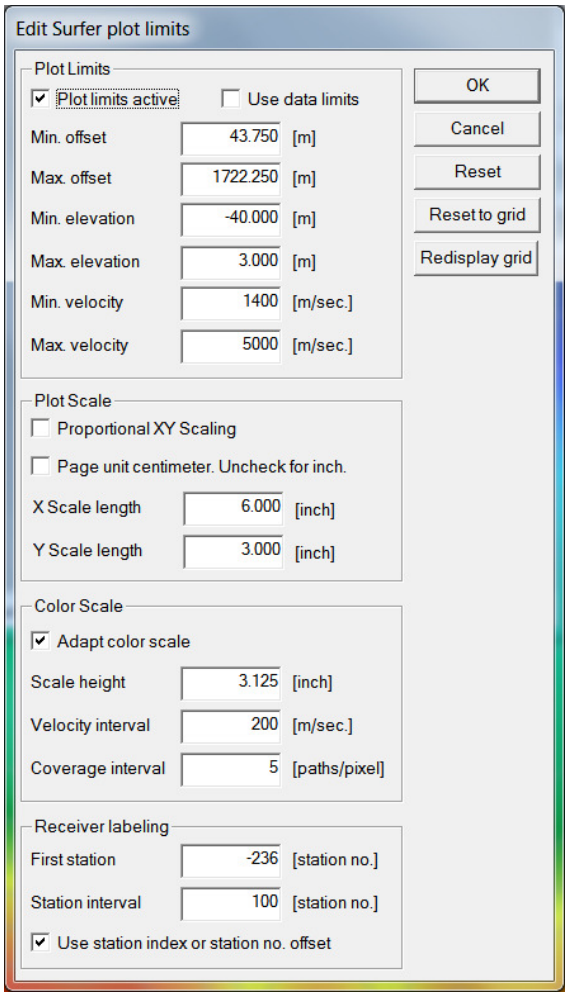

Fig. 8 (left) : *Grid|Surfer plot Limits* dialog .

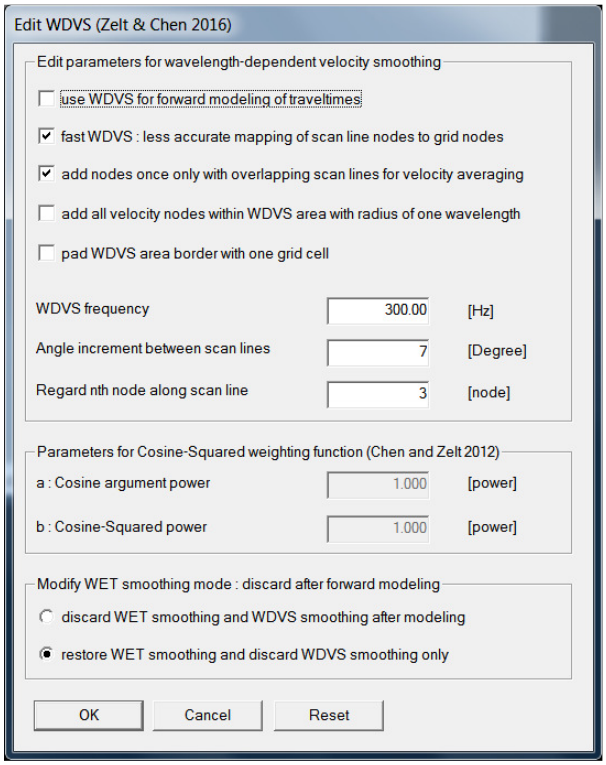

Fig. 9 : *Model|WDVS Smoothing* dialog .

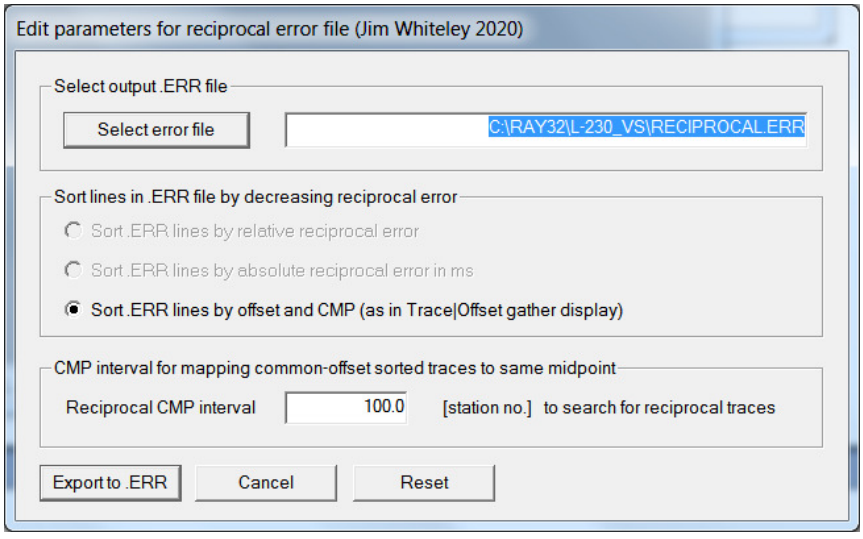

Fig. 10 : *Trace|Export reciprocal errors and update database*

Plot your reciprocal traveltime picks on shot-sorted trace gathers :

Plotting your reciprocal traveltime picks on shot-sorted trace gathers lets you quality-control your first break picks and check the validity of your recording geometry specification (shot station numbers and receiver station numbers) :

- select ***Trace\Export reciprocal traveltime picks and update database***
- click button *Select error file* and click *Save* button (Fig. 10)
- set field ***Reciprocal CMP interval [station no.]*** to 100.0 (Fig. 10)
- click button *Export to .ERR*
- optionally check new option ***Trace\Open Refractor\Shot CMP breaks with Shot gather***
- select *Trace\Shot gather* to obtain a window display as in our Fig. 1
- check new version 4.05 option ***Display\Show reciprocal picks on Shot Gather***
- browse and zoom trace gathers with function keys F7/F8, F1/F2 etc. as usual
- navigate traces with arrow-left and arrow-right keys
- if a reciprocal pick was determined and matched to the current trace then this is plotted as a green dot on the trace
- also we show ***Reciprocal Shot/Channel*** and ***Reciprocal offset[m]/CMP*** in status bar at bottom of application window (Fig. 1 bottom) if a reciprocal pick is available in the .ERR file

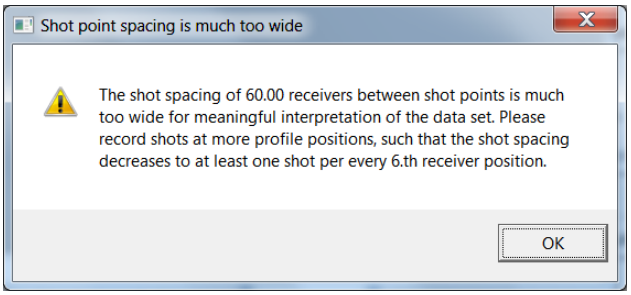

Fig. 11 : Dismiss this prompt with OK button. This prompt is not relevant for marine refraction data recorded at continuous incremental positions with towed streamer.

Here is the link to the .RAR archive with the L-320_VS profile folder for above Fig. 6 :

https://www.dropbox.com/scl/fi/62lohzw5wqnxofmof6wh8/L-230_VS_Nov21_2024.rar?rlkey=fgg2ll0na3r52qkod1wtroo1a&st=rc2wepds&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

Automatic DeltatV and interactive WET inversion

Next we show *Automatic DeltatV* inversion to obtain our pseudo-2D DeltatV initial model. We enable DeltatV option *Suppress velocity artefacts*. Then we use the DeltatV starting model grid DELTATV.GRD for interactive WET inversion using *minimal WET smoothing*. Also we lower the *WET wavepath frequency* from default 50Hz to 20Hz. We increase the *WET wavepath width* from default 3.5 percent to 10 percent :

- check option ***DeltatV\Deltat Settings\Suppress velocity artefacts*** . See Fig. 12.
- select *DeltatV\Automatic DeltatV and WET inversion*
- confirm prompt to obtain the pseudo-2D DeltatV starting model. See Fig. 14.
- when prompted to continue with WET inversion click *No* button
- select *Model\Forward model traveltimes* and `C:\Ray32\L-230_VS\TOMO\DELTATV.GRD`
- select *Grid\Image and contour velocity* and `C:\Ray32\L-230_VS\TOMO\DELTATV.GRD` to get Fig. 14
- select *WET Tomo\Interactive WET* and edit main dialog as in Fig. 13 (left)
- click button *Edit velocity smoothing* and check radio button *Minimal smoothing* (Fig. 13 at right)
- click buttons *Accept parameters* and *Start tomography processing* (Fig. 13) to obtain Fig. 15 and 16

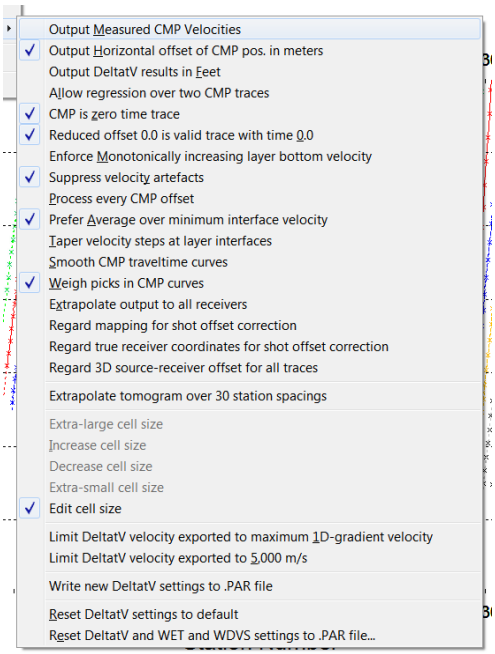

Fig. 12 : check option *Supress velocity artefacts* in *DeltatV|DeltatV Settings* menu. Leave all other DeltatV settings at their default setting.

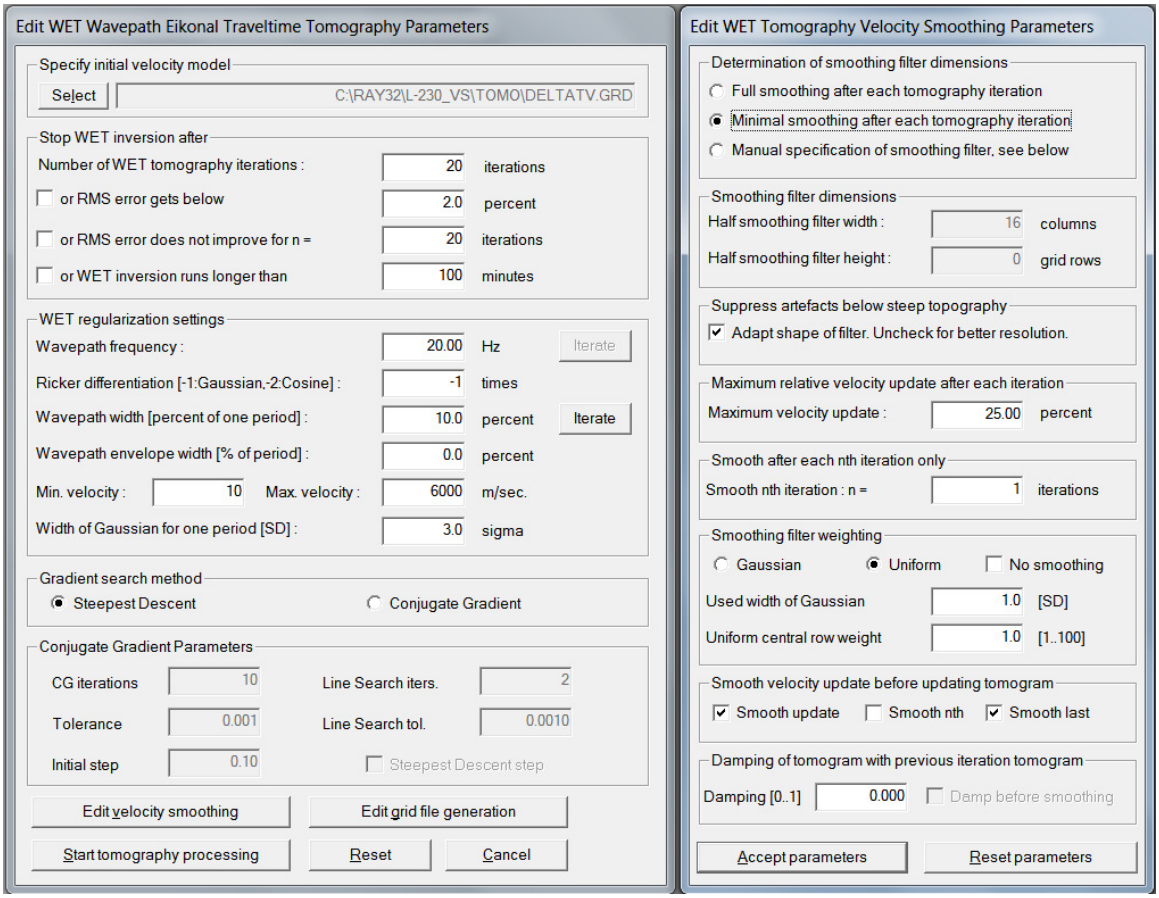

Fig. 13 : *WET Tomo|Interactive WET* with DeltatV starting model. Edit main dialog as shown at left. Click button *Edit velocity smoothing* and edit velocity smoothing as shown at right. Click buttons *Accept parameters* and *Start tomography processing* to obtain Fig. 15 and 16.

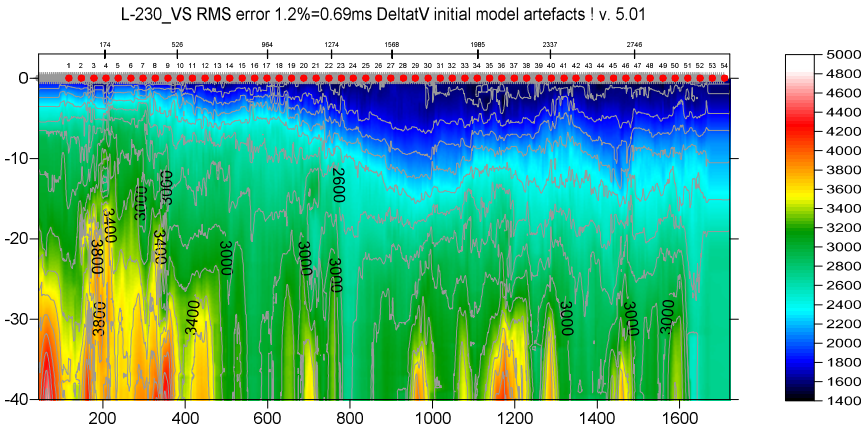

Fig. 14 : pseudo-2D DeltatV starting model obtained with *DeltatV|Automatic DeltatV and WET inversion* with option *DeltatV|DeltatV Settings|Suppress velocity artefacts* enabled (Fig. 12). RMS error is 0.69ms.

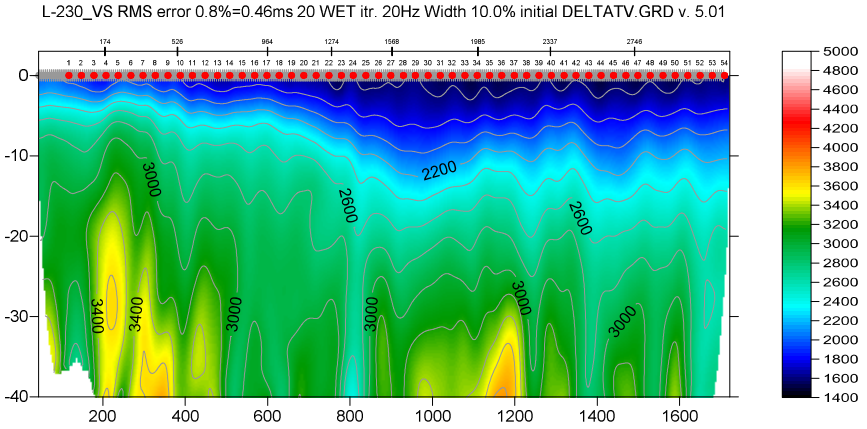

Fig. 15 : *WET Tomo|Interactive WET* (Fig. 13) with DeltatV starting model (Fig. 14). *WET frequency* 20Hz. *WET wavepath width* 10 percent. Minimal WET smoothing. Don't discard WET smoothing (Fig. 9). Leave WDVS smoothing disabled (Fig. 9).

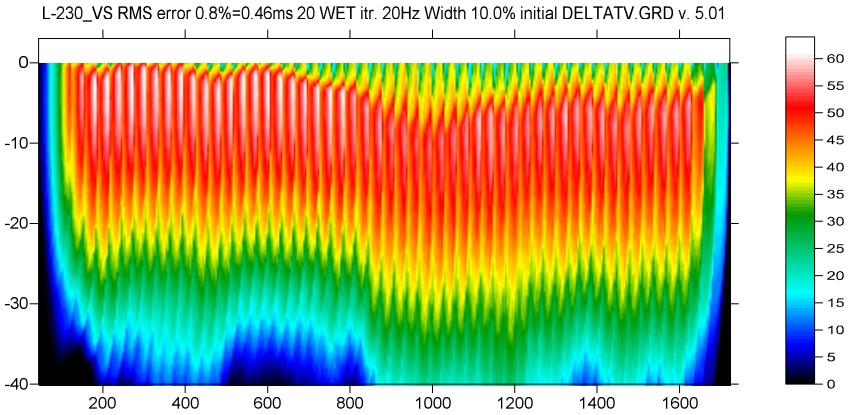

Fig. 16 : WET wavepath coverage plot obtained with Fig. 15. Unit is wavepaths per grid cell.

When comparing Fig. 6 (Smooth invert using *1D-gradient starting model*) with Fig. 15 using *pseudo-2D DeltatV starting model* :

- note the lower velocities at bottom of the WET tomogram in Fig. 15 than in Fig. 6
- also note the good match of lateral velocity variation between Fig. 6 and Fig. 15 down to 20m below topography. At greater depths Fig. 15 shows stronger lateral velocity variation than Fig. 6.
- the RMS misfit for Fig. 15 at 0.46ms is almost as low as for Fig. 6 at 0.44ms
- also the RMS error for the *pseudo-2D DeltatV starting model* is really low already at 0.69 ms (Fig. 14)

Here is the link to the .RAR archive with the L-320_VS profile folder for above Fig. 15 :

https://www.dropbox.com/scl/fi/7dwu98z4a1vovwn4zwtl8/L-230_VS_Nov23_2024_DeltatV_and_WET.rar?rlkey=j5erbeebat4crvanxany2pcxp&st=v415nmht&dl=0

If you know the bathymetry (sea-floor elevation) along the profile then you can use our *WET Tomo|WET velocity constraints* dialog to blank the water layer with a Surfer .BLN blanking file and a blanking velocity of 1,500 m/s. See our earlier marine refraction tutorial https://rayfract.com/tutorials/SR6.pdf .

Obtain layered refraction starting model using our CMP Intercept-Time refraction method :

Next we show layered refraction interpretation with our CMP Intercept-Time refraction method and using this as starting model for interactive WET inversion :

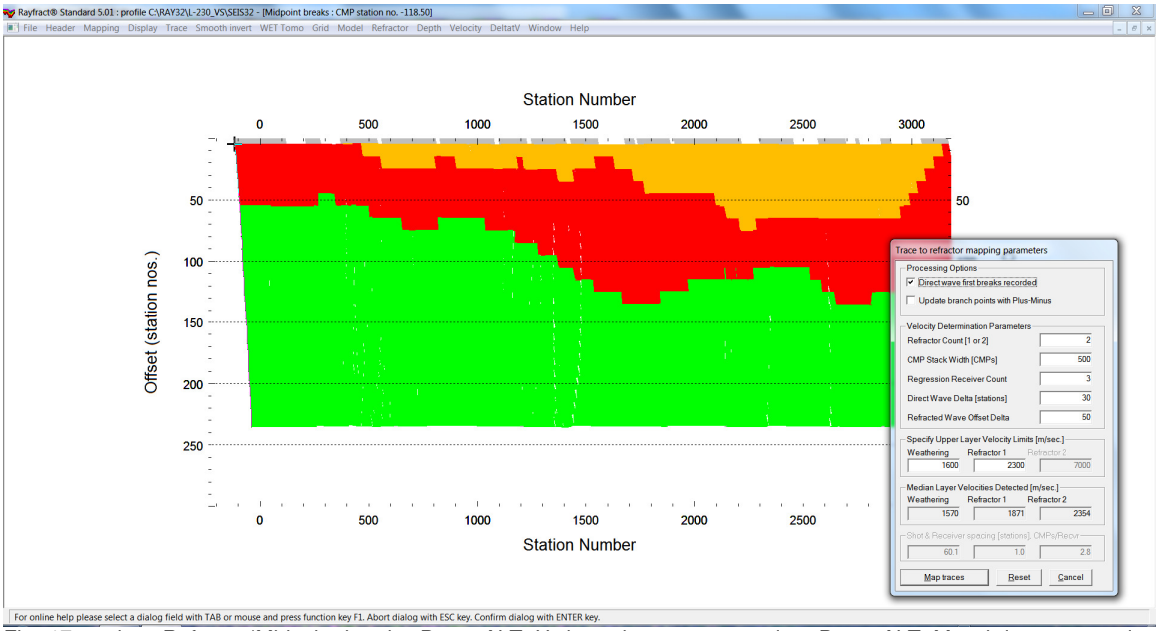

Fig. 17 : select *Refractor|Midpoint breaks*. Press ALT+U do undo current mapping. Press ALT+M to bring up mapping parameters dialog. Edit as in Fig. 18 and click button *Map traces*. Press ALT+G to bring up Crossover smoothing dialog. Edit as in Fig. 19 and click Accept button.

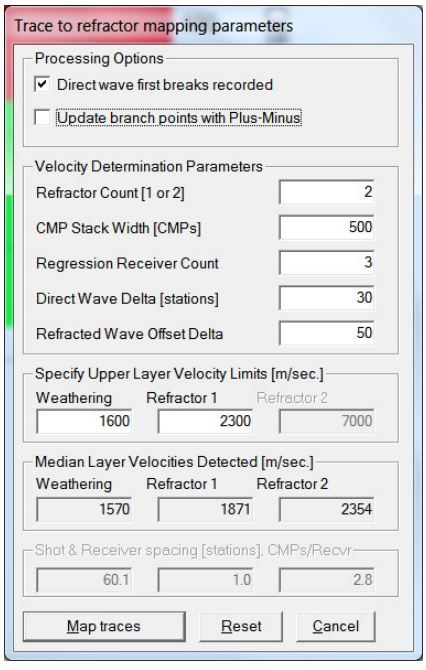

Fig. 18 : press ALT+M in *Refractor|Midpoint breaks*. Edit as shown and click *Map traces*.

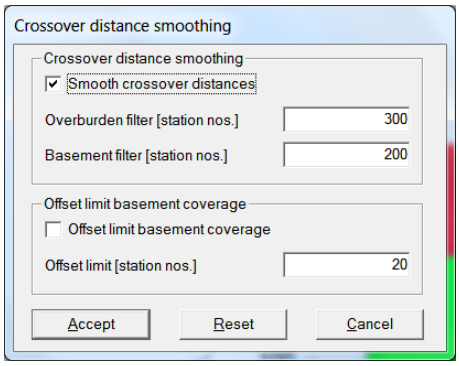

Fig. 19 : press ALT+G. Edit crossover smoothing parameters as shown. Click *Accept* button.

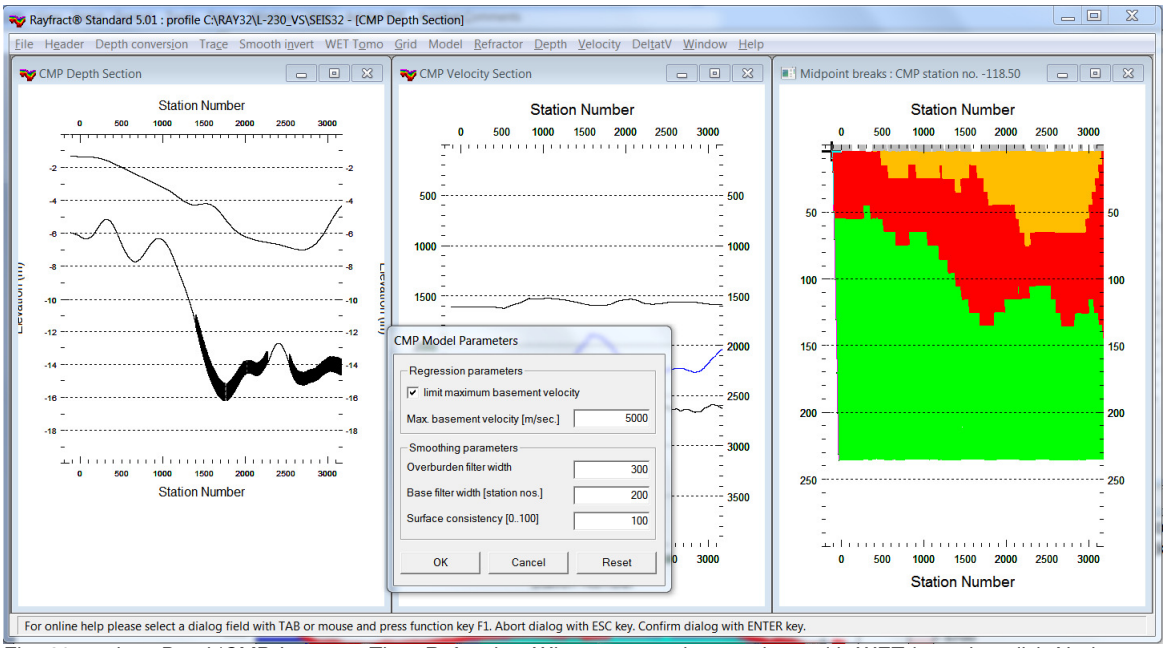

Fig. 20 : select *Depth|CMP Intercept-Time Refraction*. When prompted to continue with WET inversion click No button. Click on title bar of CMP Depth Section window. Press ALT+M and edit CMP Model Parameters as shown. Click OK.

- select *Refractor|Midpoint breaks* (Fig. 17)
- press ALT+M and edit mapping parameters (Fig. 18) and click button *Map traces*
- press ALT+G to edit the Crossover smoothing (Fig. 19). Edit as shown and click *Accept* button.
- select *Depth|CMP Intercept-Time Refraction*
- confirm warning prompt about artefacts to obtain layered refraction starting model (Fig. 20 and 21)
- when prompted to continue with WET inversion click *No* button. Redo mapping in Fig.17/18/19.
- reselect *Depth|CMP Intercept-Time Refraction*. Click on title bar of *CMP Depth Section* window.
- press ALT+M and edit *CMP Model Parameters* as shown in Fig. 20
- click *OK* button to obtain updated Fig. 20 and Fig. 21

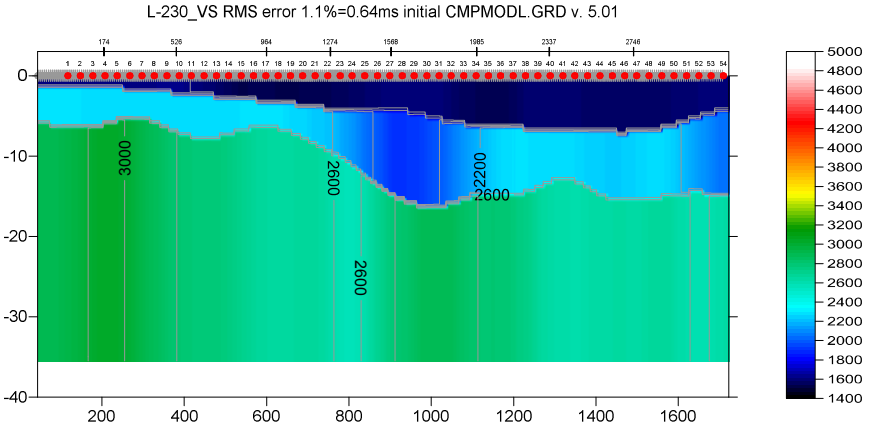

Fig. 21 : select *Depth|CMP Intercept-Time Refraction* after mapping traces to refractors (Fig. 17/18/19). When prompted to continue with WET inversion click No button. Redo mapping in Fig. 17/18/19. Reselect *Depth|CMP Intercept-Time Refraction*. Press ALT+M and edit CMP Model Parameters (Fig. 20) and click OK button to obtain our CMP Intercept-Time refraction starting model.

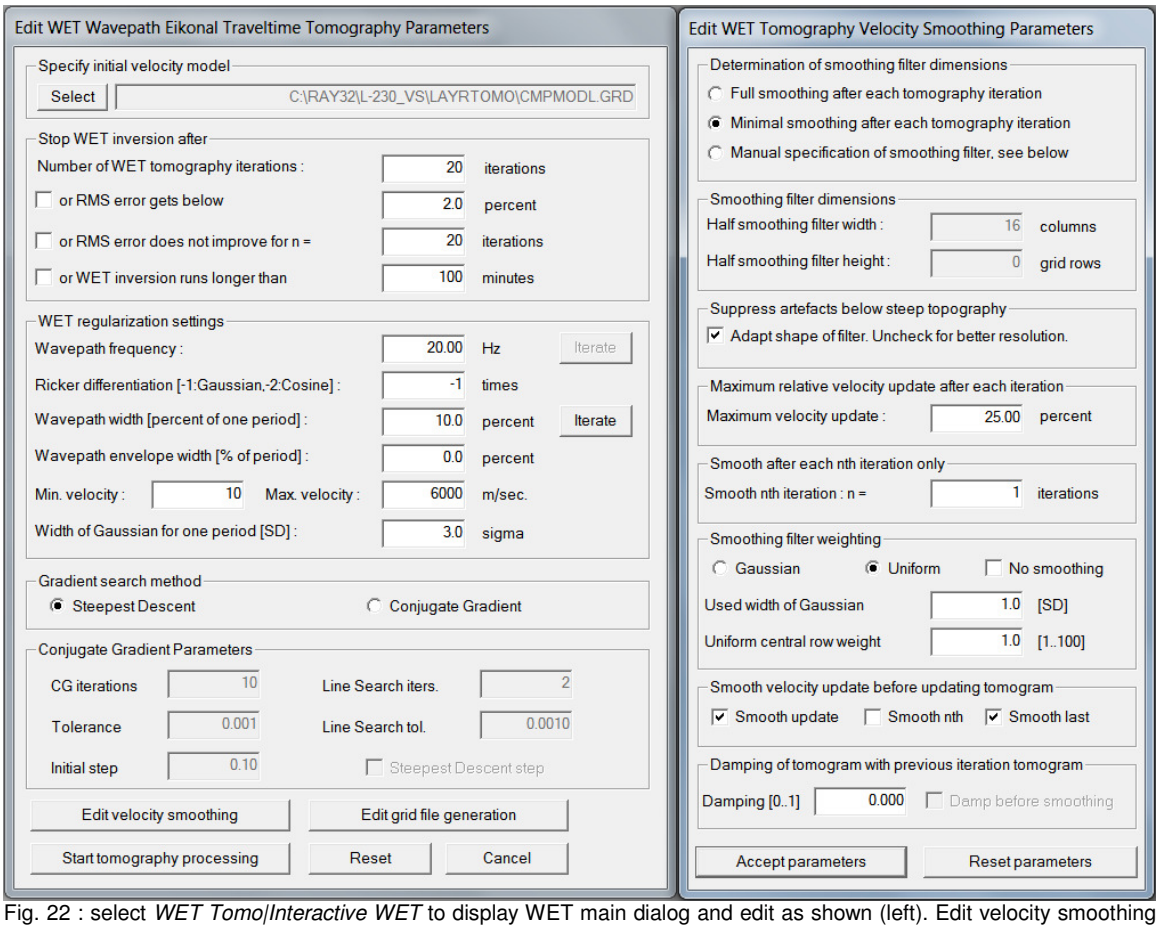

Fig. 22 : select *WET Tomo|Interactive WET* to display WET main dialog and edit as shown (left). Edit velocity smoothing (right). Click buttons *Accept parameters* and *Start tomography processing* to obtain Fig. 24 and 25.

<u>Run interactive WET inversion using our CMP Intercept-Time Refraction starting model :</u>

- select *Model|WDVS Smoothing*. Edit as in Fig. 9 and click *OK* button.
- select *WET Tomo|Interactive WET* (Fig. 22 left). Edit main dialog as shown.
- click button *Edit velocity smoothing* and edit as in Fig. 22 at right.
- click buttons *Accept parameters* and *Start tomography processing* (Fig. 22) to obtain Fig. 24 & 25

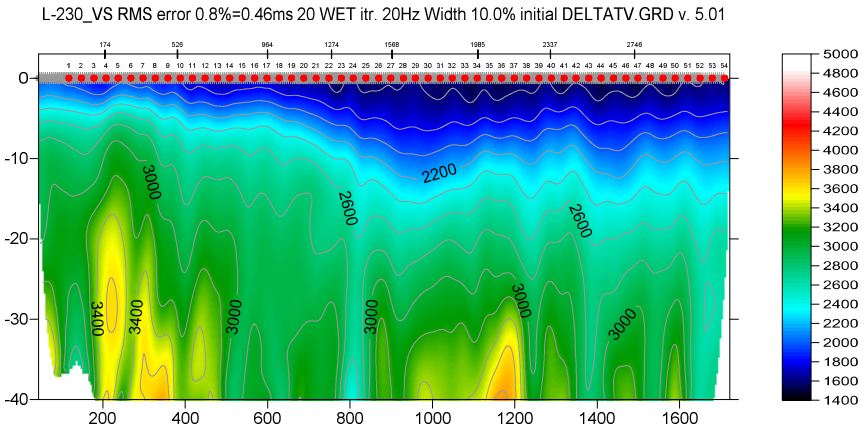

Fig. 23 : same as Fig. 15. *WET Tomo*/*Interactive WET* (Fig. 13) with DeltatV starting model (Fig. 14). *WET frequency* 20Hz. *WET wavepath width* 10 percent. Minimal WET smoothing. Don't discard WET smoothing (Fig. 9). Leave WDVS smoothing disabled (Fig. 9).

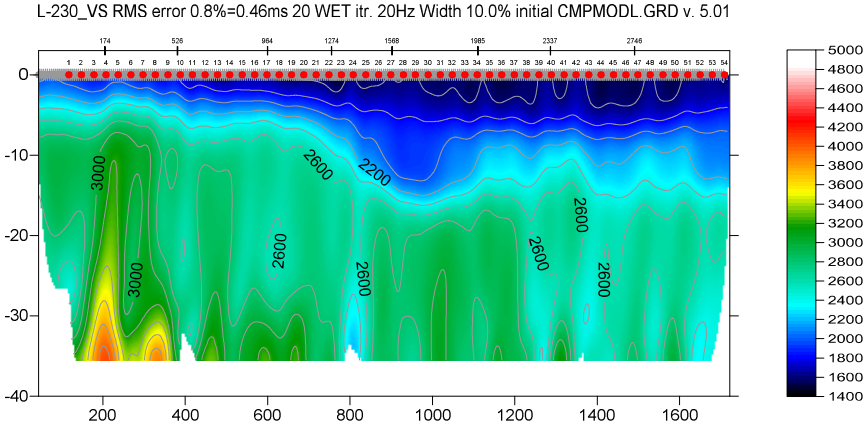

Fig. 24 : 20 Steepest-Descent WET iterations. Starting model is Fig. 21. Don't discard WET smoothing after forward modeling. WDVS disabled (Fig. 9). Minimal WET smoothing (Fig. 22 right). WET *wavepath frequency* 20Hz. WET *wavepath width* 10 percent. *Ricker differentiation* -1 [Gaussian]. *Max. WET velocity* 6,000 m/s (Fig. 22 left).

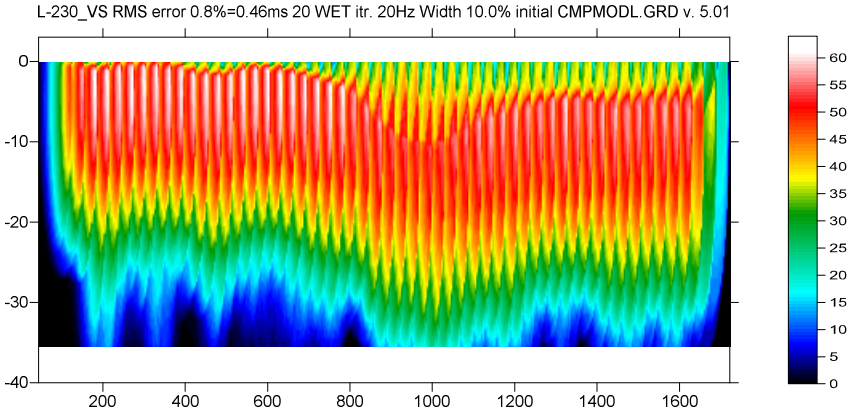

Fig. 25 : WET wavepath coverage plot obtained with Fig. 24. Unit is wavepaths per grid cell.

We compare Fig. 23 using *DeltatV starting model* with Fig. 24 using *CMP Intercept-Time starting model* :

- note the lower velocities at bottom of the WET tomogram in Fig. 24 than in Fig. 23
- good match of lateral velocity variation between Fig. 24 and Fig. 23 down to 35m below topography.
- the RMS misfit for Fig. 24 at 0.46ms is just as low as for Fig. 23 at 0.46ms
- the RMS error for the *CMP Intercept-Time starting model* is really low already at 0.64 ms (Fig. 21)

Here is the link to the .RAR archive with the L-320_VS profile folder for above Fig. 24 :

https://www.dropbox.com/scl/fi/ov0xqpghi266sddhcwjpk/L-230_VS_Nov24_2024_CMPIntercept_and_WET.rar?rlkey=0lmluphtpp8gks3wqz3fwomqu&st=54ldn9ru&dl=0

References

Hiltunen, D. R., Hudyma, N., Quigley, T. P., & Samakur, C. 2007. Ground Proving Three Seismic Refraction Tomography Programs. Transportation Research Record, 2016(1), 110–120. https://doi.org/10.3141/2016-12
https://www.researchgate.net/publication/242072938 .

Rohdewald, S.R.C. 2021a. Improving the resolution of Fresnel volume tomography with wavelength-dependent velocity smoothing, Symposium on the Application of Geophysics to Engineering and Environmental Problems Proceedings : 305-308. https://doi.org/10.4133/sageep.33-169 . Slides at https://rayfract.com/pub/SAGEEP%202021%20slides.pdf

Rohdewald, S.R.C. 2021b. Improved interpretation of SAGEEP 2011 blind refraction data using Frequency-Dependent Traveltime Tomography, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-4214, https://doi.org/10.5194/egusphere-egu21-4214

Schuster, Gerard T. and Quintus-Bosz, Aksel 1993. Wavepath eikonal traveltime inversion : Theory. Geophysics, volume 58, pp. 1314-1323. https://dx.doi.org/10.1190/1.1443514

Sheehan J.R., Doll W.E. and Mandell W.A. 2005a. An Evaluation of Methods and Available Software for Seismic Refraction Tomography. Journal of Environmental and Engineering Geophysics, volume 10, pp. 21-34. ISSN 1083-1363, Environmental and Engineering Geophysical Society. JEEG March 2005 issue. https://dx.doi.org/10.2113/JEEG10.1.21 . https://rayfract.com/srt_evaluation.pdf
https://www.researchgate.net/publication/242159023

Watanabe Toshiki et al. 1999. Seismic traveltime tomography using Fresnel volume approach. SEG Houston 1999 Meeting, Expanded Abstracts. https://www.researchgate.net/publication/240735641 .
https://dx.doi.org/10.1190/1.1820777

Zelt, C. A. and J. Chen 2016. Frequency-dependent traveltime tomography for near-surface seismic refraction data, Geophys. J. Int., 207, 72-88, 2016. See https://dx.doi.org/10.1093/gji/ggw269 and https://www.researchgate.net/publication/305487180 .

Zelt, C.A., Haines, S., Powers, M.H. et al. 2013. Blind Test of Methods for Obtaining 2-D Near-Surface Seismic Velocity Models from First-Arrival Traveltimes, JEEG, Volume 18(3), 183-194. https://www.researchgate.net/publication/267026965